CLAIMS

1. A method of obtaining channel estimates, the method comprising:

receiving a preamble across a channel, the preamble including a training sequence;

performing a Fourier transform of the training sequence;

deriving initial channel estimates in the frequency domain with the received preamble and a stored preamble;

receiving data symbols across the channel;

demodulating and decoding the data symbols; and

updating the channel estimate using the demodulated and decoded data symbols.

2. The method of claim 1, wherein said updating the channel estimate comprises updating the channel estimate by .performing operations on the demodulated and decoded data symbols, the operations excluding multiplication operations.

3. The method of claim 2, wherein the operations include addition and shift operations.

4. The method of claim 1, wherein the preamble includes two or more training sequences.

5. The method of claim 4, further comprising averaging the two or more training sequences of the preamble.

6. The method of Claim 5, wherein averaging the two training sequences may be expressed as:

$\overline{P}_k = \frac{\left(\overline{P}_k + \overline{P}_{k+N/2}\right)}{2}$ for k = 0, 1, 2, ..., N/2 -1, where $\overline{P}_k$ represents a first received preamble sequence in the time domain, and $\overline{P}_{k+N/2}$ represents a second received preamble sequence.

7. The method of Claim 1, wherein the channel is in an orthogonal frequency division multiplexing (OFDM) system.

8. The method of claim 1, further comprising performing the Fourier transform to obtain a received preamble, and wherein said deriving the initial channel estimates comprises deriving initial channel estimates in the frequency domain with the received preamble and the stored preamble.

9. The method of Claim 1, wherein the preamble comprises a pre-determined number of excited subcarriers and non-excited subcarriers.

10. The method of Claim 9, wherein the preamble comprises excited subcarriers for subcarriers k = +/-2, +/-4, ... +/-100.

11. The method of Claim 9, further comprising interpolating the channel estimates for the unexcited subcarriers.

12. The method of Claim 1, further comprising transmitting an orthogonal frequency division multiplexing symbol of the preamble, the preamble comprising a first group of excited subcarriers and a second group of subcarriers being set to zero in the frequency domain, the preamble comprising two or more training sequences in the time domain.

13. The method of Claim 12, wherein the preamble in a frequency domain is

$$\overline{P}_k \begin{cases} \pm 1 & \text{for } k = \pm 2, \pm 4, \ \ldots \pm 100 \\ 0 & \text{for } k = 0, \pm 1, \pm 3, \ldots \pm 99, \pm 101, \pm 102, \ldots, \pm 127, -128 \end{cases}$$

where k is a subcarrier number.

14. The method of Claim 1, further comprising using the two or more training sequences for correlation, wherein the two or more training sequences are identical.

15. The method of Claim 1, wherein said demodulating yields $\overline{P}_k$ for k = 0, +/-1, +/-2,..., +/-63, -64.

16. The method of Claim 1, further comprising linearly interpolating the channel estimates as expressed by $\overline{H}_{2k+1,0} = \frac{\left(\overline{H}_{2k,0} + \overline{H}_{2k+2,0}\right)}{2}$.

17. The method of Claim 1, further comprising using decoded, decision data symbols to update the channel estimates.

18. The method of claim 1, further comprising using data symbols decoded using a Viterbi algorithm to update the channel estimates.

19. The method of Claim 1, further comprising using Kalman adaptive filtering to update the channel estimates.

20. The method of Claim 19, wherein a channel update may be expressed as

$$\overline{\mathrm{H}}_{k,n+1} = \left(1-\frac{1}{n}\right)\cdot\overline{\mathrm{H}}_{k,n} + \frac{1}{n}\cdot\frac{\overline{\mathrm{Y}}_{k,n}}{Dec(\overline{\mathrm{X}}_{k,n})}.$$

21. The method of Claim 19, further comprising making a hard decision of which constellation point is closest to a received subcarrier in order to update the channel estimates.

22. The method of Claim 1, further comprising using a Least Mean Square adaptive filtering to update the channel estimates.

23. The method of Claim 22, wherein a channel update is expressed as

$$\overline{\mathrm{H}}_{k,n+1} = \begin{cases} \overline{\mathrm{H}}_{k,n} + 2\mu\left(\overline{\mathrm{Y}}_{k,n} - \overline{\mathrm{H}}_{k,n}Dec\left(\overline{\mathrm{X}}_{k,n}\right)\right)Dec\left(\overline{\mathrm{X}^{*}_{k,n}}\right) & for\ \mathrm{P_k} \neq 0 \\ \overline{\mathrm{H}}_{k,n} + 2\mu_1\left(\overline{\mathrm{Y}}_{k,n} - \overline{\mathrm{H}}_{k,n}Dec\left(\overline{\mathrm{X}}_{k,n}\right)\right)Dec\left(\overline{\mathrm{X}^{*}_{k,n}}\right) & for\ \mathrm{P_k} = 0 \end{cases}.$$

24. The method of Claim 1, further comprising using an exponential update adaptive filtering to update the channel estimates.

25. A communication device comprising:

a receiver;

a Fourier transform module operable to perform a Fourier transform of a training sequence received in a preamble in a frequency domain;

a channel estimator operable to derive initial channel estimates in the frequency domain using the received preamble and a stored preamble;

a decoder to demodulate and decode received data symbols; and

an update module operative to update the channel estimate using the demodulated and decoded data symbols.

26. The communication device of claim 25, wherein the update module is operative to update the channel estimate by performing operations on the demodulated and decoded data symbols, the operations excluding multiplication operations.

27. The communication device of claim 26, wherein the operations include addition and shift operations.

28. The communication device of claim 25, wherein the preamble includes two or more training sequences.

29. The communication device of claim 28, further comprising an averaging module to average the two or more training sequences of the preamble.

30. The communication device of claim 29, wherein averaging the two training sequences may be expressed as:

$\overline{P}_k = \frac{(\overline{P}_k + \overline{P}_{k+N/2})}{2}$ for k = 0, 1, 2, ..., N/2 -1, where $\overline{P}_k$ represents a first received preamble sequence in the time domain, and $\overline{P}_{k+N/2}$ represents a second received preamble sequence.

31. The communication device of claim 25, wherein the channel is an orthogonal frequency division multiplexing (OFDM) channel.

32. The communication device of claim 25, further comprising a module operative to obtain a received preamble from an output of the Fourier transform module, and wherein the channel estimator is operative to derive initial channel estimates in the frequency domain with the received preamble and the stored preamble.

33. The communication device of claim 25, wherein the preamble comprises a pre-determined number of excited subcarriers and non-excited subcarriers.

34. The communication device of claim 33, wherein the preamble comprises excited subcarriers for subcarriers k = + /-2, +/-4, ... +/-100.

35. The communication device of Claim 33, wherein the channel estimator is operative to interpolate the channel estimates for the unexcited subcarriers.

36. The communication device of Claim 25, wherein the preamble includes an orthogonal frequency division multiplexing symbol, the preamble comprising a first group of excited subcarriers and a second group of subcarriers

being set to zero in the frequency domain, the preamble comprising two or more training sequences in the time domain.

37. The communication device of claim 36, wherein the preamble in a frequency domain is

$$\overline{\mathrm{P}}_k \begin{cases} \pm 1 & for\ k = \pm 2, \pm 4, \ \ldots \pm 100 \\ 0 & for\ k = 0, \pm 1, \pm 3, \ldots \pm 99, \pm 101, \pm 102, \ldots, \pm 127, -128 \end{cases}$$

where k is a subcarrier number.

38. The communication device of claim 25, wherein the channel estimator is operative to use the two or more training sequences for correlation, wherein the two or more training sequences are identical.

39. The communication device of claim 25, wherein said demodulating yields $\overline{\mathrm{P}}_k$ for k = 0, +/-1, +/-2,..., +/-63, -64.

40. The communication device of claim 25, wherein the channel estimator is operative to linearly interpolate the channel estimates as expressed by $\overline{\mathrm{H}}_{2k+1,0} = \frac{\left(\overline{\mathrm{H}}_{2k,0} + \overline{\mathrm{H}}_{2k+2,0}\right)}{2}$.

41. The communication device of Claim 25, wherein the update module is operative to update the channel estimates using decoded, decision data symbols.

42. The communication device of claim 25, wherein the update module is operative to update the channel estimate using data symbols decoded using a Viterbi algorithm.

43. The communication device of claim 25, wherein the update module is operative to update the channel estimate using Kalman adaptive filtering.

44. The communication device of claim 43, wherein a channel update may be expressed as

$$\overline{H}_{k,n+1} = \left(1-\frac{1}{n}\right)\cdot\overline{H}_{k,n} + \frac{1}{n}\cdot\frac{\overline{Y}_{k,n}}{Dec(\overline{X}_{k,n})}.$$

45. The communication device of claim 43, wherein the update module is operative to make a hard decision of which constellation point is closest to a received subcarrier in order to update the channel estimates.

46. The communication device of claim 25, wherein the update module is operative to update the channel estimate using a Least Mean Square adaptive filtering.

47. The communication device of claim 46, wherein a channel update is expressed as

$$\overline{H}_{k,n+1} = \begin{cases} \overline{H}_{k,n} + 2\mu\left(\overline{Y}_{k,n} - \overline{H}_{k,n} Dec\left(\overline{X}_{k,n}\right)\right) Dec\left(\overline{X^{*}_{k,n}}\right) & \mathit{for}\ P_k \neq 0 \\ \overline{H}_{k,n} + 2\mu_1\left(\overline{Y}_{k,n} - \overline{H}_{k,n} Dec\left(\overline{X}_{k,n}\right)\right) Dec\left(\overline{X^{*}_{k,n}}\right) & \mathit{for}\ P_k = 0 \end{cases}.$$

48. The communication device of claim 25, wherein the update module is operative to update the channel estimate using an exponential update adaptive filtering.

49. A communication device comprising:

means for receiving preambles and data symbols;

means for performing a Fourier transform of a training sequence received in a preamble;

means for deriving initial channel estimates in the frequency domain using the received preamble and a stored preamble;

means for demodulating and decoding received data symbols; and

means for updating the channel estimate using the demodulated and decoded data symbols.

50. The communication device of claim 49, further comprising means' for updating the channel estimate by performing operations on the demodulated and decoded data symbols, the operations excluding multiplication operations.

51. The communication device of claim 50, wherein the operations include addition and shift operations.

52. The communication device of claim 49, wherein the preamble includes two or more training sequences.

53. The communication device of claim 52, further comprising means for averaging the two or more training sequences of the preamble.

54. The communication device of claim 53, wherein averaging the two training sequences may be expressed as:

$\overline{\mathrm{P}}_k = \frac{\left(\overline{\mathrm{P}}_k + \overline{\mathrm{P}}_{k+N/2}\right)}{2}$ for k = 0, 1, 2, ..., N/2 -1, where $\overline{\mathrm{P}}_k$

represents a first received preamble sequence in the time domain, and $\overline{\mathrm{P}}_{k+N/2}$ represents a second received preamble sequence.

55. The communication device of claim 49, wherein the channel is an orthogonal frequency division multiplexing (OFDM) channel.

56. The communication device of claim 49, further comprising:

means for obtaining a received preamble from the Fourier transform; and

means for deriving initial channel estimates in the frequency domain with the received preamble and the stored preamble.

57. The communication device of claim 49, wherein the preamble comprises a pre-determined number of excited subcarriers and non-excited subcarriers.

58. The communication device of claim 57, wherein the preamble comprises excited subcarriers for subcarriers k = +/-2, +/-4, … +/-100.

59. The communication device of claim 57, further comprising means for interpolating the channel estimates for the unexcited subcarriers.

60. The communication device of claim 49, wherein the preamble includes an orthogonal frequency division multiplexing symbol, the preamble comprising a first group of excited subcarriers and a second group of subcarriers being set to zero in the frequency domain, the preamble comprising two or more training sequences in the time domain.

61. The communication device of claim 60, wherein the preamble in a frequency domain is

$$\overline{P}_k \begin{cases} \pm 1 & for\ k = \pm 2, \pm 4, \ \ldots \pm 100 \\ 0 & for\ k = 0, \pm 1, \pm 3, \ldots \pm 99, \pm 101, \pm 102, \ldots, \pm 127, -128 \end{cases}$$

where k is a subcarrier number.

62. The communication device of claim 49, further comprising means for using the two or more training sequences for correlation, wherein the two or more training sequences are identical.

63. The communication device of claim 49, wherein said demodulating yields $\overline{P}_k$ for k = 0, +/-1, +/-2,..., +/-63, -64.

64. The communication device of claim 49, further comprising means for linearly interpolate the channel estimates as expressed by $\overline{H}_{2k+1,0} = \frac{(\overline{H}_{2k,0} + \overline{H}_{2k+2,0})}{2}$.

65. The communication device of claim 49, further comprising means for updating the channel estimates using decoded, decision data symbols.

66. The communication device of claim 49, further comprising means for updating the channel estimate using data symbols decoded using a Viterbi algorithm.

67. The communication device of claim 49, further comprising means for updating the channel estimate using Kalman adaptive filtering.

68. The communication device of claim 67, wherein a channel update may be expressed as

$$\overline{H}_{k,n+1} = \left(1-\frac{1}{n}\right)\cdot\overline{H}_{k,n} + \frac{1}{n}\cdot\frac{\overline{Y}_{k,n}}{Dec(\overline{X}_{k,n})}.$$

69. The communication device of claim 67, further comprising means for making a hard decision of which constellation point is closest to a received subcarrier in order to update the channel estimates.

70. The communication device of claim 49, further comprising means for updating the channel estimate using a Least Mean Square adaptive filtering.

71. The communication device of claim 70, wherein a channel update is expressed as

$$\overline{H}_{k,n+1} = \begin{cases} \overline{H}_{k,n} + 2\mu\left(\overline{Y}_{k,n} - \overline{H}_{k,n}Dec\left(\overline{X}_{k,n}\right)\right)Dec\left(\overline{X^{*}_{k,n}}\right) & for\ P_k \neq 0 \\ \overline{H}_{k,n} + 2\mu_1\left(\overline{Y}_{k,n} - \overline{H}_{k,n}Dec\left(\overline{X}_{k,n}\right)\right)Dec\left(\overline{X^{*}_{k,n}}\right) & for\ P_k = 0 \end{cases}.$$

72. The communication device of claim 49, further comprising means for updating the channel estimate using an exponential update adaptive filtering.

73. A computer program for obtaining a channel estimate, the computer program comprising the steps of:

performing a Fourier transform of a training sequence received in a preamble across a channel;

deriving initial channel estimates in the frequency domain with the received preamble and a stored preamble;

demodulating and decoding the data symbols received across the channel; and

updating the channel estimate using the demodulated and decoded data symbols.

74. The computer program of claim 73, wherein said updating the channel estimate comprises updating the channel estimate by performing operations on the demodulated and decoded data symbols, the operations excluding multiplication operations.

75. The computer program of claim 74, wherein the operations include addition and shift operations.

76. The computer program of claim 73, wherein the preamble includes two or more training sequences.

77. The computer program of claim 76, further comprising averaging the two or more training sequences of the preamble.

78. The computer program of Claim 77, wherein averaging the two training sequences may be expressed as:

$\overline{P}_k = \frac{(\overline{P}_k + \overline{P}_{k+N/2})}{2}$ for k = 0, 1, 2, …, N/2 -1, where $\overline{P}_k$

represents a first received preamble sequence in the time domain, and $\overline{P}_{k+N/2}$ represents a second received preamble sequence.

79. The computer program of Claim 73, wherein the channel is in an orthogonal frequency division multiplexing (OFDM) system.

80. The computer program of claim 73, further comprising performing the Fourier transform to obtain a received preamble, and wherein said deriving the initial channel estimates comprises deriving initial channel estimates in the frequency domain with the received preamble and the stored preamble.

81. The computer program of Claim 73, wherein the preamble comprises a pre-determined number of excited subcarriers and non-excited subcarriers.

82. The computer program of Claim 81, wherein the preamble comprises excited subcarriers for subcarriers k = + /-2, +/-4, ... +/-100.

83. The computer program of Claim 81, further comprising interpolating the channel estimates for the unexcited subcarriers.

84. The computer program of Claim 73, further comprising transmitting an orthogonal frequency division multiplexing symbol of the preamble, the preamble comprising a first group of excited subcarriers and a second group of subcarriers being set to zero in the frequency domain, the preamble comprising two or more training sequences in the time domain.

85. The computer program of Claim 84, wherein the preamble in a frequency domain is

$$\overline{P}_k \begin{cases} \pm 1 & for\ k = \pm 2, \pm 4, \quad \ldots \pm 100 \\ 0 & for\ k = 0, \pm 1, \pm 3, \ldots \pm 99, \pm 101, \pm 102, \ldots, \pm 127, -128 \end{cases}$$

where k is a subcarrier number.

86. The computer program of Claim 73, further comprising using the two or more training sequences for correlation, wherein the two or more training sequences are identical.

87. The computer program of Claim 73, wherein said demodulating yields $\overline{P}_k$ for k = 0, +/-1, +/-2, ..., +/-63, -64.

88. The computer program of Claim 73, further comprising linearly interpolating the channel estimates as expressed by $\overline{H}_{2k+1,0} = \frac{(\overline{H}_{2k,0} + \overline{H}_{2k+2,0})}{2}$.

89. The computer program of Claim 73, further comprising using decoded, decision data symbols to update the channel estimates.

90. The computer program of claim 73, further comprising using data symbols decoded using a Viterbi algorithm to update the channel estimate.

91. The computer program of Claim 73, further comprising using Kalman adaptive filtering to update the channel estimates.

92. The computer program of Claim 91, wherein a channel update may be expressed as

$$\overline{H}_{k,n+1} = \left(1 - \frac{1}{n}\right) \cdot \overline{H}_{k,n} + \frac{1}{n} \cdot \frac{\overline{Y}_{k,n}}{Dec(\overline{X}_{k,n})}.$$

93. The computer program of Claim 91, further comprising making a hard decision of which constellation

point is closest to a received subcarrier in order to update the channel estimates.

94. The computer program of Claim 73, further comprising using a Least Mean Square adaptive filtering to update the channel estimates.

95. The computer program of Claim 95, wherein a channel update is expressed as

$$\overline{H}_{k,n+1} = \begin{cases} \overline{H}_{k,n} + 2\mu\left(\overline{Y}_{k,n} - \overline{H}_{k,n}Dec\left(\overline{X}_{k,n}\right)\right)Dec\left(\overline{X^{*}_{k,n}}\right) & for\, P_k \neq 0 \\ \overline{H}_{k,n} + 2\mu_1\left(\overline{Y}_{k,n} - \overline{H}_{k,n}Dec\left(\overline{X}_{k,n}\right)\right)Dec\left(X^{*}_{k,n}\right) & for\, P_k = 0 \end{cases}.$$

96. The computer program of Claim 73, further comprising using an exponential update adaptive filtering to update the channel estimates.

97. The method of claim 1, wherein the method is performed in an IEEE 802.11a-compliant system.

98. The method of claim 1, wherein the method is performed in an IEEE 802.16a-compliant system.

99. The device of claim 26, wherein the method is performed in an IEEE 802.11a-compliant system.

100. The device of claim 25, wherein the method is performed in an IEEE 802.16a-compliant system.

101. The device of claim 49, wherein the method is performed in an IEEE 802.11a-compliant system.

102. The device of claim 49, wherein the method is performed in an IEEE 802.16a-compliant system.

103. The computer program of claim 73, wherein the method is performed in an IEEE 802.11a-compliant system.

104. The computer program of claim 73, wherein the method is performed in an IEEE 802.16a-compliant system